spring grain were not injured. Corn, potatoes, and hops made satisfactory progress.—*G. N. Salisbury.*

West Virginia.—Hot, showery weather prevailed during the first three weeks, and was very beneficial for crop growth. The cutting of hay and oats and the stacking of wheat were considerably delayed, but the fourth week was very favorable for this work. Corn made rapid growth and was very promising. Pastures and stock were in fine condition. Millet, buckwheat, cowpeas, cabbages, and gardens were doing well.—*E. C. Vose.*

Wisconsin.—The month was characterized by a deficiency of rainfall, moderate temperature, a good supply of sunshine, and severe local hailstorms. Tobacco was damaged considerably by hail and grains were generally lodged by high winds. Corn made rapid headway. Hay was well secured and was an unusually large crop, nothwithstanding damage by adverse weather conditions earlier in the season. Spring grains made good progress. Pastures and meadows were in excellent condition. Fruits and berries were a heavy yield. Sugar beets continued in fine condition. The apple crop was not in satisfactory condition.—*J. W. Schaeffer.*

Wyoming.—The weather was favorable for the growth of grain and gardens, which made favorable progress; at the close of the month gardens were in excellent condition, and a good crop of grain was beginning to ripen in the earlier sections. A good crop of native hay was being secured, but showers interfered with its harvest. Ranges continued excellent and cured very slowly, in some sections remaining green to the close of the month. All stock was in excellent condition.—*W. S. Palmer.*

SPECIAL ARTICLES.

STUDIES ON THE DIURNAL PERIODS IN THE LOWER STRATA OF THE ATMOSPHERE.

By Prof. FRANK H. BIGELOW.

V.—THE VARIABLE ACTION OF THE SUN AND ITS EFFECT UPON TERRESTRIAL WEATHER CONDITIONS.

APPLICATIONS TO THE PROBLEMS OF THE WEATHER.

The foregoing correlation of the connections between the phenomena of temperature, pressure, vapor tension, atmospheric electricity, ionization, and magnetic vectors seems to give a natural unity to these data which have been detached from one another in the previous scientific researches. The entire train of causes and effects is arranged by it in a satisfactory sequence, so that we are for the first time in a position to summarize the masses of evidence lying before us. It will be now possible, having a clear working hypothesis before us, to indicate the proper manner of continuing the investigations with every prospect of reaching a successful practical result. I propose in the remaining papers of this series to lay down a working program for American meteorologists to use, including in that term those astrophysicists who are interested in the sources of our radiant energy, as well as the climatologist and the forecaster who are concerned with the effects of radiation upon climatic and weather variations. The first paper will contain a popular statement of the general conditions; the second, a more technical account of the theoretical aspects of the problem of cosmical meteorology; and the third, a description of the organization of the Mount Weather Research Observatory which is designed to mediate between the theoretical and the practical sides of the subject.

THE SUN A VARIABLE STAR.

In order to bring out the underlying reason for believing that variable solar action is responsible, at least indirectly, for changes in the terrestrial weather from year to year, it is necessary to show in what way the sun is itself unequal in its internal movements. The sun is an immense solid-liquid mass, 866,000 miles in diameter, surrounded by a gaseous envelope which gradually changes to rarefied matter similar to that seen in vacuum tubes. Recent computations indicate that at the center of the sun there is a nucleus which instead of being gaseous is nearly as solid as the interior of the earth, with a temperature of about 10,000° centigrade; the average density of the whole sun is 1.43 times that of water, and this is located at half the distance from the center to the surface; the surface density is not far from 0.37 that of water, and its temperature, according to my calculation, ranges between 7000° and 6000° centigrade; at the surface there is a sudden transition from liquids to gases, which occurs as an explosion, caused by the uprush of liquids from the interior. The solar mass in such a physical state while rotating on its axis sets up a peculiar circulation, in consequence of which at the surface a huge wave is formed like a tide that advances most rapidly in the equatorial belt.

The body of the sun is divided up into layers of different temperatures, like a set of dice boxes inside one another, the longest axis extends through the sun from pole to pole, and these slide by one another at different velocities. This produces a stronger discharge of warm material in the polar regions than near the equator, so that on the sun the heat is greatest at the poles, reversing the conditions with which we are familiar in the earth's atmosphere.

The evidence for these facts is found in a study of the (1) sun spots, which occur in belts within 35° of the equator; (2) the faculæ or fleecy cloud-like forms found on all parts of the sun's surface, but most abundantly around the spots; (3) the prominences or gaseous flames projected in all latitudes above the disk; and (4) the coronas, which extend to great distances from the surface and somewhat resemble auroras in their nature.

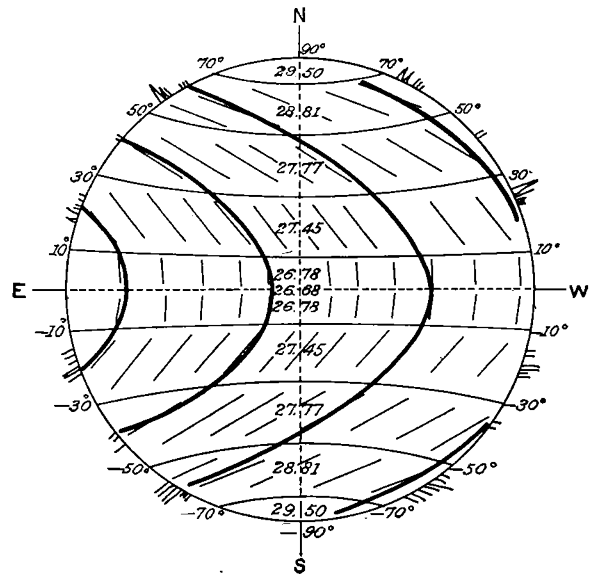

FIG. 64.

The visible surface is divided for convenience into successive zones beginning at the equator as shown on fig. 64, where the advancing equatorial wave is indicated, the time of rotation being marked in different latitudes with 26.68 days at the equator, increasing to 29.50 days at the poles. The time of the rotation of the internal solid nucleus is not known. There are some arguments for supposing it to be 26.00 days, and others for making it 26.68 days, but the subject has not yet yielded to study. The above periods of rotation are those seen from the earth as it passes around the sun in its orbit of 365 days.

Fig. 65 gives an excellent idea of the visible surface. This is mottled with cloud-like forms resembling the heads of cumulus clouds, and probably they represent the tops of columns of liquid or gaseous matter rising from the interior; there are three minute sun spots to be seen on it, and extensive regions of white calcium flocculi in the sun-spot belts. The spectroheliograph has developed the power to make pictures like this at different levels in the sun's atmosphere, representing sections through it, so that the action of the vapors and gases surrounding a spot can be studied at several elevations, just as we make out the cloud forms at different levels in the earth's atmosphere by their types. In this picture the details are quite perfectly brought out.

Fig. 66 is an illustration of a great sun spot and the clouds or the flocculi in its neighborhood. Three or four such section pictures are made one over the other, wherein the forms change gradually from the lowest level to the highest. It is very probable that the true circulation in the region of the spots can be determined by examining the details of such pictures. The sun spots of the winter 1904-5 closely resemble the one in this illustration in size and appearance.

Fig. 67 gives some examples of quiescent and eruptive prominences or hydrogen flames, as observed at Kalocsa Observatory. The forms resemble flash illuminations in clouds during storms where no lightning discharge occurs, and are probably due to the light from the photosphere passing through rarefied layers of gas, in about the same way that the aurora illumination is formed. Electrical glow discharges and magnetic forces are probably in operation at the same time. The eruptive prominences are due to uprushes of gas exploding from the surface. The liquids in the interior are at very great pressure and temperature, but on reaching the surface this pressure diminishes suddenly and the liquid explodes into gaseous formations such as are shown. Enormous velocities up to 1000 miles per hour are indicated, and great altitudes up to 300,000 miles above the surface have been noted.

Beyond the limits of the gaseous constituents of the sun extends the corona which reaches altitudes of from 1,000,000 to 5,000,000 miles above the sun's surface. The lower section of fig. 68 gives four typical shapes, one at the minimum of solar activity, one at the maximum, one at the rising, and one at the falling phase. At the minimum the polar region is capped with a ray-like structure in which the streamers bend away to either side, as if they were the lines of force in a magnetic field surrounding a spheroidal magnet. At the maximum of the period the coronal forms are confused and no definite structure is preserved, indicating that some cause is operating to obscure the beautiful magnetic structure seen at the minimum when the sun is not very active. The corona of the sun can not be observed except during total eclipses, but it is found by comparing the forms secured during the past 40 years that it passes through a well defined cycle, repeated in about 11 years, as is indicated in the diagram. The next total eclipse will occur on August 29-30, 1905, and will be visible in Spain and northern Africa. Parties are already being formed in the United States to make observations on that occasion.

The passage from a quiet to a strongly agitated condition of the sun is marked also by other remarkable variations in phenomena which are visible from the earth. The upper section of fig. 68 gives the relative frequency of the sun-spot area as computed at the Greenwich Observatory. A minimum occurred in 1889, a maximum in 1894, and a second minimum in 1900, about 11 years later. The height of the shaded area is proportional to the number of sun spots seen on the sun, and it indicates that the rate of increase following the minimum is more rapid than the rate of decrease following the maximum. Similar curves of sun-spot frequency have been constructed for the last century, and in them it is found that there is considerable irregularity in the curve from one period to another, so that the 11-year period is merely an average of the range between 8 years and 14 years. On comparing the sun-spot curve with the changes in the magnetic and electric fields as observed on the earth, that is to say with the positions assumed by the magnetic needle and with the auroral displays in the polar regions, it is shown that these three systems are in very close accordance, and it is conceded that some relation of cause and effect prevails. The inference that the difference in the number of spots is the cause of the corresponding change in the earth's electricity or magnetism is not sustained by more minute examination of the details, except in a general way. The better theory is that the internal solar action produces all of these phenomena simultaneously, as the effects of an underlying cause which is not yet fully understood.

We can, perhaps, convey some idea of the present state of the investigation in the following way. The difficulty of the research has been due to the fact that the sun spots are only a sluggish register of the true solar action which causes the variable weather conditions, and it has been a great task to discover a better pulse. In 1894 the author published some results of a study of the meteorological conditions in the United States for the interval 1878-1893, in which it was found that the barometric pressure and the temperature vary slightly, not only in an 11-year period, but, also, in a 3-year period which is more clearly defined. In the same work it appeared that the average position of the storm tracks in the United States sways up and down in latitude, and also that the speed with which the storms drift eastward varies in the same short period. The annual magnetic field gives both periods in combination, the 3-year period superposed upon the 11-year period, thus making the inference probable that

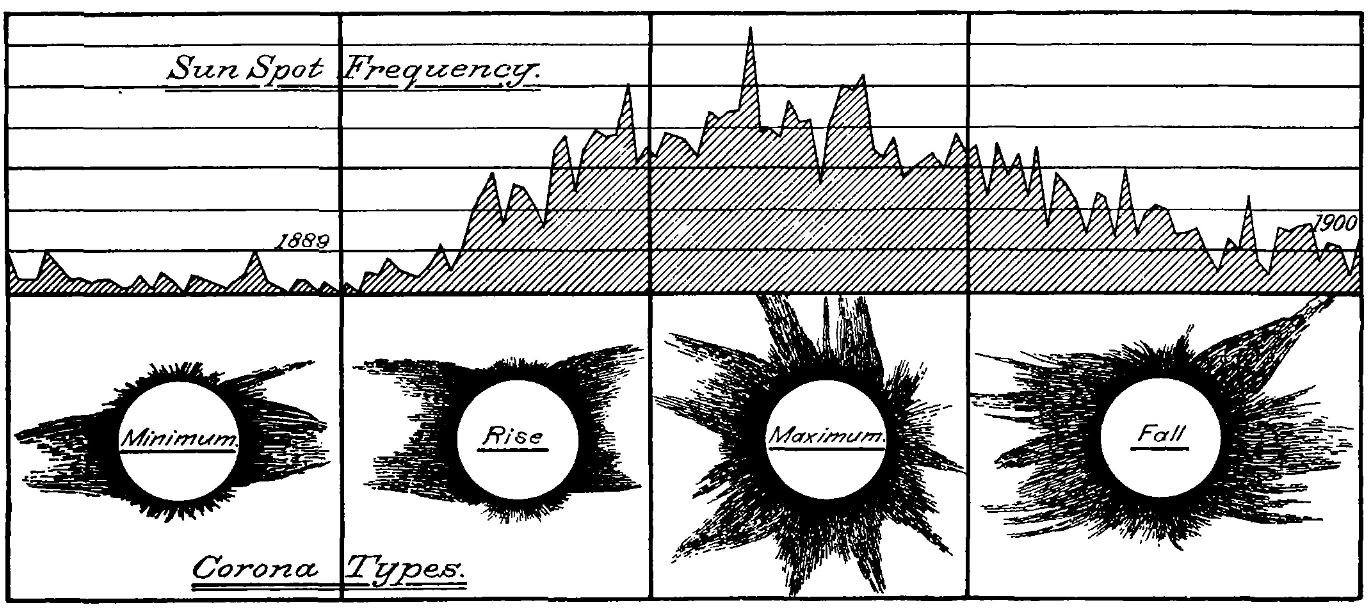

FIG. 68.

both periods in the meteorological and magnetic elements depend upon solar operations. Unfortunately the sun spots show us the 11-year period strongly and the 3-year period very feebly. This point has recently been cleared up by a study of the solar prominences, which have been continuously observed by the Italian spectroscopists since 1871.

Fig. 69 shows that great variations occur in the number of the prominences and the faculæ, the former being represented by the red marks on the diagram, and the latter by the blue marks. In the year of minimum activity, 1889, both prominences and faculæ are very few in number, but in the year of maximum activity, 1894, they are very abundant in the central zones, the prominences extending into the higher latitudes.

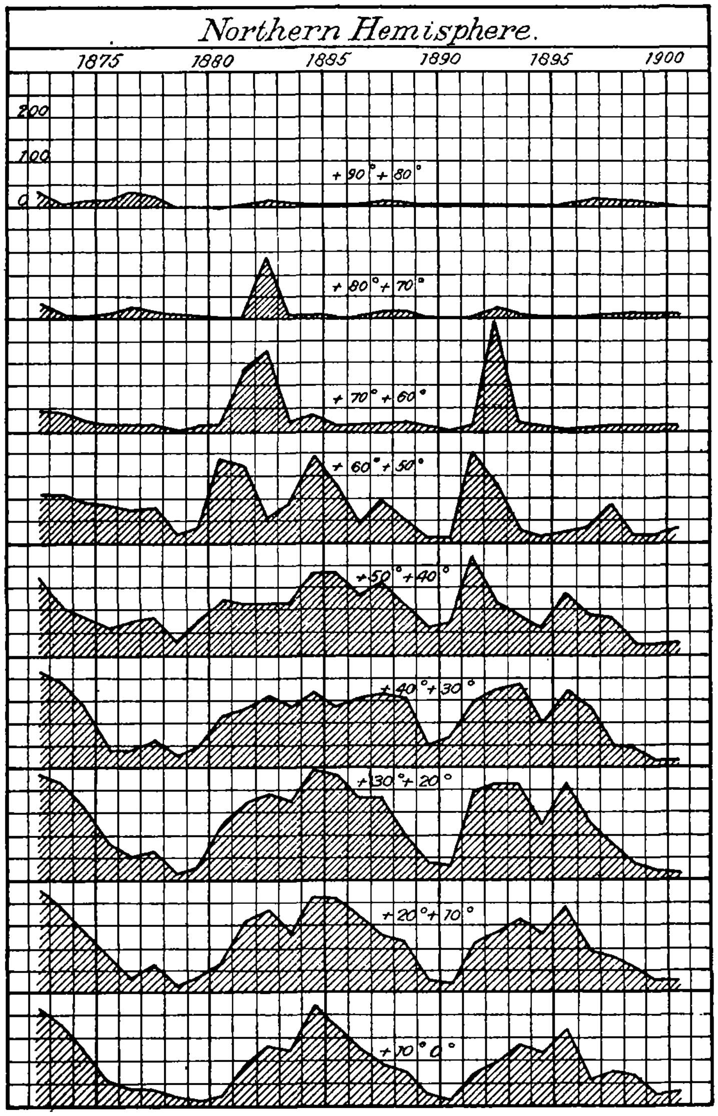

FIG. 70.

These eruptions on the surface of the sun move up and down the solar disk by a law of their own, and this must depend upon the internal energy of the sun, which, like a variable star, is passing through a series of periodic convulsions in its process of evolution. Lockyer, in 1902, published the result of his discussion of the prominences, as they occur in each 10-degree zone between the two poles of the sun. Thus, it is seen by fig. 70, for the Northern Hemisphere, how different the distribution of the prominences is in latitude. In the equatorial regions,[1] where the spots prevail, the 11-year period is very pronounced, though there are signs of the 3-year period in connection with it. On the other hand, in the higher latitudes,[2] the 11-year period diminishes in importance and the 3-year period supersedes it.

THE SYNCHRONOUS METEOROLOGICAL CONDITIONS ON THE EARTH.

Now, it happens that the frequency variation of the solar prominences in the higher latitudes gives the key that was wanted to enable us to study the meteorological conditions in the earth's atmosphere with some prospect of success. This variation shows that the meteorological pulse is registered most favorably not in the sun-spot belts, but in the zones of the sun corresponding with the temperate zones of the earth, from latitude 30° to 60°. In the polar zones in certain years the prominence frequency is very well marked, and these years correspond with the years of special activity in the earth's electric and magnetic fields.

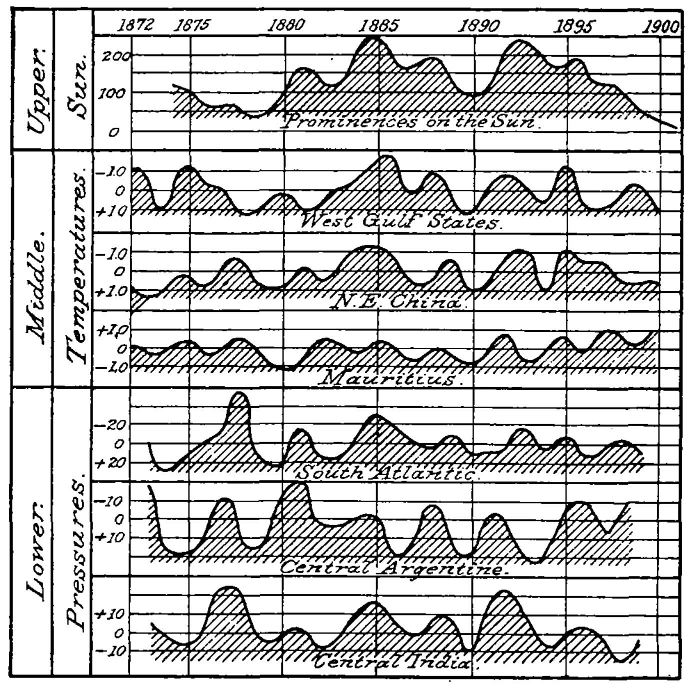

FIG. 71.

In order to extend the comparison of the solar-terrestrial conditions further, I computed the annual mean pressure and annual mean temperature for the series of years, 1872–1900, over many portions of the earth, comprising records for several hundred stations. They were grouped together by countries and a few of the curves are brought together in fig. 71. In the upper section of this figure the prominence frequency on the sun is averaged for all zones, and the resulting curve contains a 3-year period superposed upon the 11-year period. The middle section, marked "temperatures," contains temperature curves from the tropical and temperate zones, and it is easily seen, by comparing the crests with the solar curve at the top, that in spite of some irregularities there is a tendency to form the same number of crests and to make them fall on the same years as the crests in the prominences. The third section, marked "pressures," gives a few curves of the variations in the annual pressures and these conform quite closely to the same system. Each curve ought to be compared with the solar curve by itself, to judge of the general fact of agreement. It should, however, be observed that this agreement is not everywhere direct, but that in certain regions an inversion takes place. Thus, the pressures do not increase simultaneously all over the earth in one year and decrease in another year, rather there is a general surging by which the atmosphere is piled up in

[1] Zones, (+ 10° 0°), (+ 20° + 10°), (+ 30° + 20°).

[2] Zones, (+ 40° + 30°), (+ 50° + 40°), (+ 60° + 50°).

one region and lowered in another during the same year. This is necessary in order to avoid the difficulty of making the total weight of the earth's atmosphere vary from year to year. When the pressure is generally high in North or South America, it is low in Asia, the Indian Ocean, and Australia. This condition is brought about by some profound modification in the circulation of the earth's atmosphere, by which high areas tend to form in one hemisphere at the same time that low areas prevail in the opposite hemisphere. In a similar way the changes of temperature from year to year are such that in the tropical zones, where the sun shines fully on the earth's surface, temperatures rise and fall directly with the solar prominence frequency; but in the middle latitudes of the earth the opposite or reverse conditions of temperature prevail. Hence, when solar activity increases and more spots or prominences can be seen, there is an increase of heat in the earth's Tropics, and this produces an increase in the circulation of the entire atmosphere. The warm air of the Tropics rises more rapidly than usual, the cold air of the upper strata over the temperate zones pours down vigorously upon the United States, Europe, and Asia, and these countries are covered with a rapid succession of pronounced cold waves, such as have marked the years 1904 and 1905.

The increase in solar activity shows itself in yet another way. By putting together the tables of prominences so as to study their behavior in longitude, that is around the sun in the same zones, it has been found that the retardation of the solar rotation in the higher latitudes relative to the primary equatorial period of 26.68 days, sways backward and forward in harmony with the same prominence frequency curve. This indicates that the internal solar energy, in trying to free itself after accumulation and congestion, sends forth great waves, which rotate the circulation in the polar zones farther backward. The visible symptoms of this operation at the surface are changes in the number and location of the prominences, the faculæ, the sun spots, the granulation of the photosphere, and in the form and extent of the great coronal streamers. Besides this visible effect of the internal action, there is the more important and invisible radiation which streams from the sun and falls upon the earth.

Besides the general synchronism in the solar action just outlined, we have a corresponding movement in the earth's atmosphere embracing the magnetic and electrical forces, the pressure, temperature, vapor tension, and precipitation. Conflicting evidence will no doubt be reconciled by a more thorough study of the underlying facts of inversion, and generally the entire subject needs most careful investigation.

THE METEOROLOGICAL WORK OF THE U. S. NAVAL ECLIPSE EXPEDITION TO SPAIN AND ALGERIA, AUGUST 30, 1905.

By Prof. FRANK H. BIGELOW. Dated Daroca, Spain, August 27, 1905.

At the request of Rear-Admiral C. M. Chester, U. S. N., Commander in Chief of the Special Service Squadron *Minneapolis*, *Dixie*, and *Cæsar*, sent to observe the total eclipse of the sun, August 30, 1905, in Spain and north Africa, the Chief of the Weather Bureau detailed myself and Dr. Stanislav Hanzlik to carry out the meteorological observations required in this connection. Advantage was taken of the voyage on the *Cæsar*, which sailed from Norfolk on June 22, to make some kite ascensions with self-recording meteorographs for data over the ocean, and, also, to observe the electrical conditions near the water areas. We secured seven ascensions on the trip to Spain, and have made suitable preparations to continue the work on the return voyage in September. The southwest current prevailing on the western side of the Atlantic reached its maximum force about 1000 miles east of Norfolk, and the northeast current on the eastern side was at a maximum less than 500 miles from Spain. The former is much broader than the latter, and the wind did not reach a velocity as great on the western side as on the eastern side of the Atlantic. We found that there was no tendency to reversal of the temperature gradients such as Hergesell observed farther to the south in the trades, and we did not note any important diurnal variation of the temperature even at short distances above the surface of the ocean, though the kites were in the air as much as eight hours during several days. The electrical observations on the *Cæsar* include a few records of the potential gradient over the side of the ship, an excellent series of observations on the coefficient of dissipation with the Elster and Geitel apparatus, and a complete set for the number of ions per cubic centimeter with the Ebert apparatus, the velocity observations being omitted. All these electrical records were made in the calm region surrounding the Azores, lying between the two great currents just mentioned.

After landing at Gibraltar the expedition separated into two branches, Doctor Hanzlik in charge of the part in Algeria, and Professor Bigelow in charge of that in Spain. The African party sailed for Bona on July 19, and the astronomical and meteorological station was established at Guelma. It was planned to organize two secondary stations to supplement the work at Guelma, but these seem to have been abandoned for some reason. The Spanish parties landed at Valencia July 24, and the work of equipping the several stations proceeded regularly to a conclusion. On July 25 a meteorological station was arranged in the Institute of Castellon, Señor Josè Sanz Bremon, Director; on July 27 another station was planned at Tortosa, or rather the Director of the Cosmical Observatory of the Ebro, Rev. P. R. Cirera, S. J., agreed to furnish copies of the regular records as desired. The plan of this observatory is similar to that of the Mount Weather Research Observatory and contains a very excellent equipment of modern instruments and a corps of competent observers. As it is located within the belt of the eclipse shadow, it ought to give a fine account of itself, having such remarkable advantages for this occasion. On July 30–August 1 the work was organized at Porta Coeli, where the astronomical station No. 2, near the southern border of the track, was located. Besides the regular meteorological instruments, an Elster and Geitel apparatus and a potential electrometer were put in operation, and Messrs. Scrivener and Straupe being left in charge. This station has been in operation for fully four weeks, a portion of the time day and night, and a very extensive series of observations is in hand.

On August 3–6 another station was installed at Daroca in connection with the astronomical station No. 1, near the center of the belt. In addition to the instruments mentioned at Porta Coeli, an Ebert apparatus for the number and velocity of the ions, a Brashear polarimeter, and a solar image telescope were set up. It was intended to execute a series of radiation observations with a mercury actinometer, but the copper box as originally made failed and it was not possible to secure a new one till too late to make that work profitable. The magnetic observations were inadequately organized at this station and will not be important in this connection. All the instruments at Daroca have been in constant use by myself aided by Messrs. Rickerd, Trainor, and Olivier, and we have obtained several thousand observations, some of the electrical series continuing uninterruptedly day and night for more than a week. From Daroca I proceeded to Zaragoza and arranged for suitable observations at the Colegio del Salvador in charge of Rev. Josè Albiñana, S. J., August 8; then to Guadalajara, where similar observations will be furnished by Lieut. Col. Pedro Vives y Vich, chief of the Spanish aerostatic service, who, also, has charge of all the balloon ascensions at Burgos undertaken by the International Committee during this eclipse. The homing pigeon service and the balloon equipment at Guadalajara were very interesting and instructive.

Plate II.

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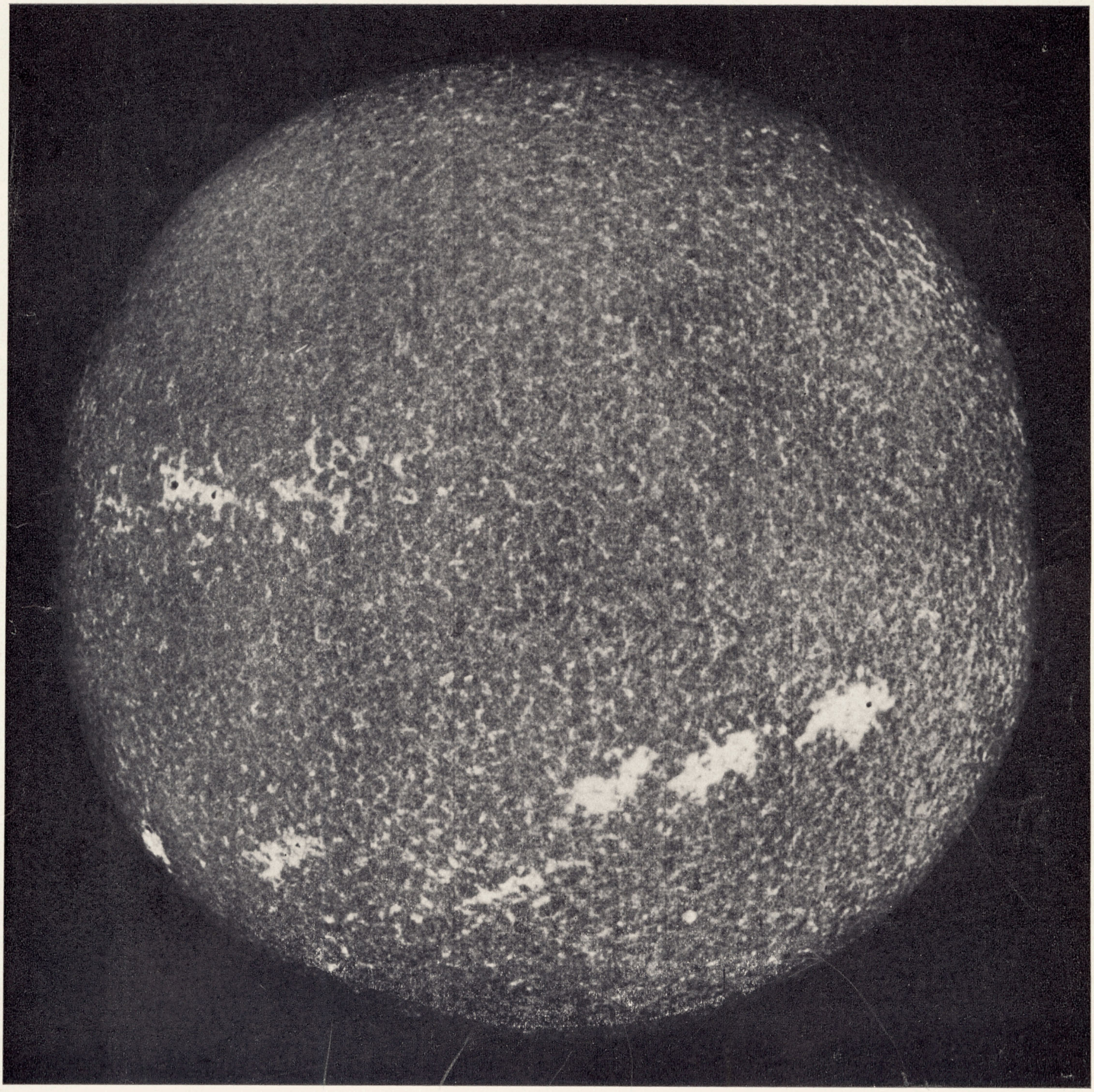

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Fig. 65.—Spectroheliograph of the sun, August 12, 1903, taken at the Yerkes Observatory, showing the spots, flocculi, and general appearance of the bright surface of the photosphere.

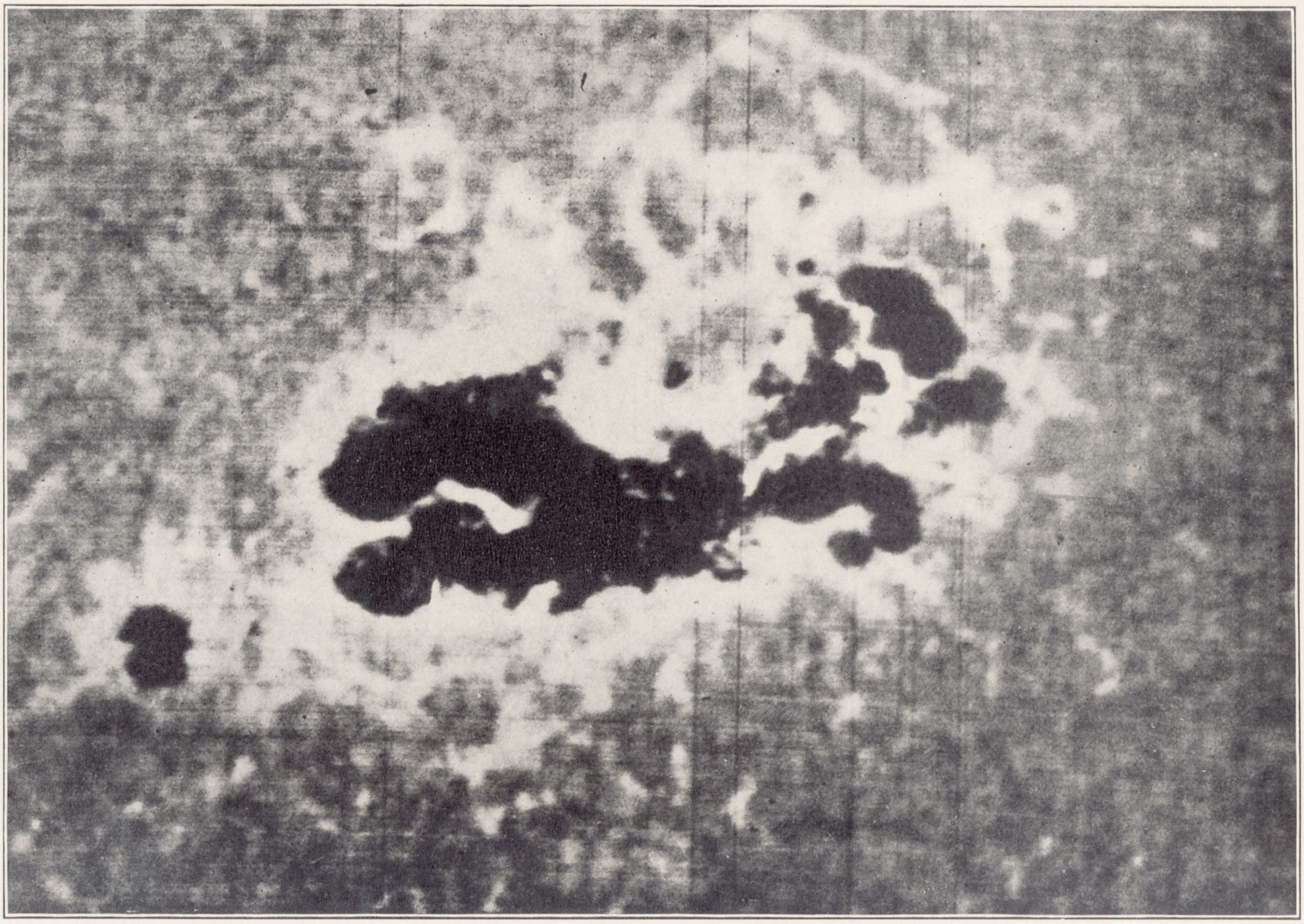

FIG. 66.—Spectroheliograph of the sun spot of October, 1903, showing the calcium flocculi surrounding it.

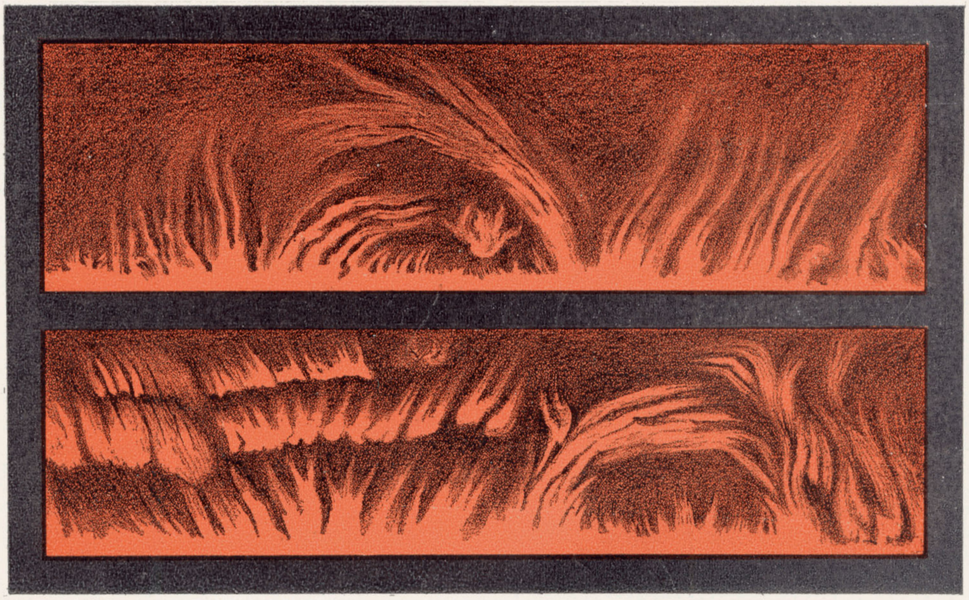

FIG. 67.—Typical forms of the solar prominences or red hydrogen flames.

Plate IV.

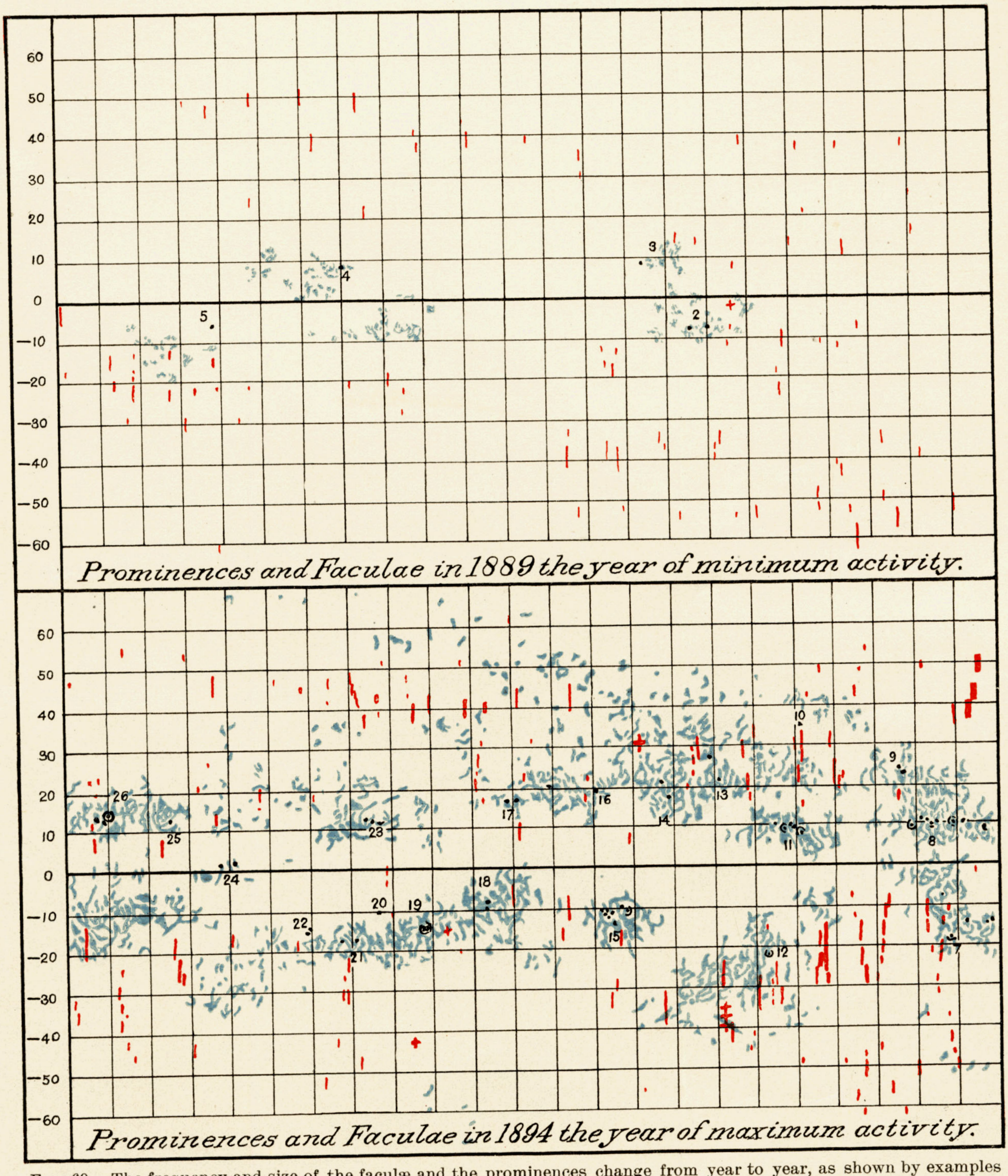

Fig. 69.—The frequency and size of the faculæ and the prominences change from year to year, as shown by examples from the minimum in 1889 and the maximum in 1894. Faculæ in blue. Prominences in red.